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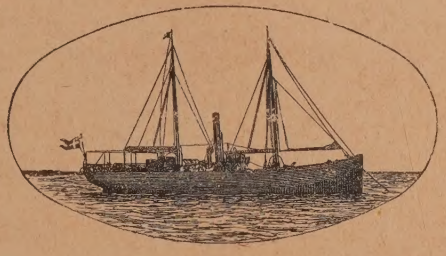
of

The Danish Biological Station

to

The Board of Agriculture.



XIV.

1906.

By

C. G. Joh. Petersen,

Ph. D.

Translated from „Fiskeri-Beretning for 1906".

Copenhagen.
Centraltrykkeriet.
1908.

From

The Danish Biological Station.

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The Influence of Light on the Migrations of the Eel.

By C. G. Joh. Petersen.

That the eel is a night-animal is well known by every one; most know also that eel-spearing is carried on at night by means of lights (flares). It is indeed the general impression everywhere, though not amongst fishermen, that these lights are used to attract the eels, whereas the truth is, that the eels flee from them; but without the lights the fishermen would never be able to see the eels at night-time. By their means a glimpse of the eel is got and then the spear is quickly brought into operation. It need not be thought that the day-time would be better for eel-spearing, because then, as a matter of fact, the eels are generally hidden under the plant-growths or at the bottom and would as a rule never be seen.

There are however exceptions to this as to every rule; an owl even may show itself in the day-time; but it is a rule that the eels mostly travel by night. The eels that are speared are usually the yellow, not the adult eels, and the eels which migrate in greatest quantity are the silver eels. To capture as many as possible of these latter whilst migrating from the Baltic through our Belts is the great task before us. Whether the light (artificial light) had any influence on the silver eels I did not know with certainty when I began these investigations in 1904; almost all I knew was only that they also shunned the flare lights and that in North Italy, in the great silver-eel fisheries, fires were sometimes lit alongside the canals in order to stop the eels migrating.

It was further known also, that the silver-eels migrate almost entirely by night and nearly always only during the nights when the moon was not shining in the evenings, that is to say, from a few days after full moon till about new moon in the so-called moonless nights.*)

I then got the desire to test whether it really was the case that the migrations of the silver-eel could be stopped by artificial light, and therefore sent the assistant of the Biological Station, cand. mag. A. Otterstrøm, to Kilen near Struer in order to make experiments. These were made in the autumn of 1904 and the result was, that a couple of petroleum-lanterns set up on posts in the narrow outlet from this brackish-water fjord, could stop the whole migration of the eels so that none were taken in a trap-net fixed across the outlet.

*) Of the many exceptions to this rule there need only be mentioned; that the eel has been seen to migrate in the day-time, that it could migrate when clouds covered the moon and that on the whole it was influenced by various atmospheric conditions; but that it greatly prefers dark to light for its migrations, no one can doubt.

Encouraged by this result, the necessary funds were granted in 1905 by the Minister of Agriculture for a larger experiment in obstruction of the passage; in the dark portion not obstructed it was proposed to set a number of eel-traps to catch all the eels, which would otherwise pass outside in the deep water (13 fathoms).

For this experiment I chose the Little Belt between Funen and Fænø, and a report on the matter was sent in some time ago.

This experiment was without result in the main, as the easterly winds drove the eels between Fænø and Jutland and the submarine apparatus with the 50 electric lamps had consequently too few eels to work upon.

In the same autumn, 1905, a second experiment was made with acetylene lamps to stop the migration of the eels from Thorsminde (Nissum Fjord), but this experiment was also without result. The various difficulties encountered, the closing of the mouth and later opening at another place etc., have but little interest in this connection.

Various technical experiences were gained in this year, 1905; these resulted in 1906 in the construction of a light-projector with aceton-acetylene, which only costs some few hundred kroner and is thus much cheaper than electricity and the acetylene lamps used in 1905, and which further is portable and easy to use. From a purely technical point of view this was a great step in advance. Mr. Schrøder, engineer in the Danish Light-house Board employ, was my technical adviser in this matter.

So much was gained however by the first experiment in 1905 that the public interest was awakened; the experiments were discussed and reported on in the newspapers, and the fishermen became afraid that those of them who fished north of the light-obstruction would get no eels, as these would be caught or stopped in their migration; and it is certain that if this method of fishing with lights becomes generally used, it will naturally be of advantage at various places to some to the disadvantage of others; but every new method of procedure does the same, and the main thing — greater receipts from our country's eel fishery — should therefore not be lost sight of. The introduction of the eel-seines caused considerable trouble and yet they have brought the country a good deal of money.

Further instances also appeared to throw light upon the matter, and almost all supported the view that light (i. e. artificial light) has some influence on the migration of the eels. An old experience that the eel does not like to pass over light stems of trees was brought forward; a fishermen tried to spear the silver-eels during their passage from Kilen by placing himself at night in the outlet at Kilen with a flare-light, but the attempt failed as no eels appeared. Another had taken nothing in his eel-traps outside Fredericia harbour so long as a large steamer lay there and let its electric light shine out during the night etc. Lastly, a note appeared in the »Fiskeri-Tidende« to the effect, that some fishermen whilst fishing for herring with driftnets had seen several hundreds of silver-eels at the surface in the Great Belt; the eels do not seem to have been afraid however of the weak lanterns on the boat.

In order to test the new acetylene light-projector and to study again the feat-

ures of the eel migration at a convenient place, I chose the outlet at Kilen for a second time.

Concerning these last experiments the following report may be given.

After waiting to no purpose in the moonless nights of August for an opportunity, when wind and stream would offer the necessary conditions for a large outward migration of eels from Kilen at Struer, we at last got these conditions on September 15th during the September moonless nights.

The migration of the eels proceeded on such a large scale, that specially good conditions were present for the investigation of the influence of light on the eels whilst migrating. The current was running out of the narrows, which was a necessary condition, and the night was dark, rainy with strong wind from the S.W. The outlet of the channel is ca. 40 feet broad and ca. 2 feet deep. It is closed by a sluice or drawbridge with 3 openings over which is the pathway. The central gate was now held open and a trap set opposite or outside it, so that but very few at any rate of the migrating eels could escape capture when they had passed through the gate. The eels began to migrate about 8 o'clock in the evening and by 9 o'clock ca. 100 lbs. were taken, according to the estimate of two fishermen who removed the eels captured in the trap into a tub.

The trap was now emptied, so far as this could be done under the circumstances, into the tub by the two fishermen who stood out in the outlet with their boots on, and in the course of the next quarter of an hour, 9.10—9.25, ca. 50 lbs. were taken according to the calculation of the fishermen. These were likewise emptied into the tub and the light-projector was then set working from 9.25—9.40, in such a way that it only shone between the arms of the trap and the sluice-gate, the latter greatly cutting off the light from the inner parts of the channel; only a quite narrow part of the water between the arms of the trap was thus lighted. At 9.40 the trap was again searched and in it was ca. 1 lb. of eels (ca. 10 specimens), the majority of which had stuck in the outer parts of the trap or had remained between its arms and the nearest corners of the sluice.

To make no mistake about the matter, I again had the trap set in the ordinary way without light from 9.45—10, and in this time ca. 75 lbs. were taken.

I now went with the projector further up the channel, where the outlet had its full breadth, ca 44 feet, in order if possible to get a sight of the migrating eels.

This was easily done by quickly throwing the light over the water so that the bottom was well lighted. On holding the light thus steady for a moment all the eels disappeared from the illuminated part; they fled from this with great swiftness both up and down the stream. Turning the light some few fathoms up the channel, the eels were again seen.

It appeared that so long as the projector was throwing its light across the outlet, very few eels came into the trap, where the two fishermen still watched out in the water. I believe that only those eels came into the trap which were between the latter and the streak of light. As soon as the light was removed from the outlet, in a minute or two the eel-migration began again and was observed by the fishermen at the trap.

Whilst the light was shining steadily across the outlet, the bottom was

well lighted up, so that we could see the small stones and plants and sometimes a smelt, which did not seem to be disturbed by the light; but no eels were seen to pass the light when it was held steady.

The projector was then placed in the middle of the outlet, so that it only lit up the one side. Its light was however so strong that the other half of the outlet was not in complete darkness, as the reflexion from obstacles, grass, bank etc, on the lighted side was strong. I wished to investigate whether by lighting up half the channel, the eels could be forced to migrate through the other half; but this was only partially successful, as though the migration did not completely stop, yet it was considerably diminished, apparently as a result of the reflexion. Further, the streak of light from the projector was fairly broad so that the light was not sufficiently concentrated, which may be easily altered however in the future by means of a shutter.

From this experiment under such fortunate conditions, only to be met with on quite few days in the year, which confirmed the experiment (with petroleum lamps) made in 1904 by Cand. Otterstrøm at the same place, I have no doubt that the migration of the eels can be completely stopped by means of light and that the projector used might have stopped the migration in an outlet considerably broader and somewhat deeper.

The eels at Kilen are almost all male eels, with 7 to 8 in the lb.; all the eels taken were fully developed silver eels.

Whether the eel migrates chiefly in the upper or lower water-layers, the experiment gave no good opportunity to investigate, as the water was shallow, 2 to 3 feet deep.

It was my intention therefore to test the action of the projector under larger conditions out in the true Lim-Fjord at Oddesund, and some few experiments were even made; but the conditions were not specially fortunate, so that nothing could be concluded.

On the other hand, we were succesful later in the Little Belt in the moonless nights of October 1906 in observing the migrating eels up in the surface of the water at night; this was managed by sailing along with »the projector fixed to the bow in front of the »Sallingsund«. The eels were seen several nights, but we never saw very many, 10—12 within a space of two hours and often but a few, so that I cannot as yet speak with certainty regarding whether it is a rule, that the silver eels migrate up in the water or not; but some do so. This observation agrees very well with that previously mentioned in the »Fiskeri-Tidende« Nr. 4, 1906, p. 27.

It may be further mentioned that another fish, the butter-fish *(Gunellus vulgaris)*, which lives quietly during the day below stones and such like, comes right up to the surface of the water at night; we saw many of them in the Little Belt during the experiment mentioned and took many with a bucket. If such can wander about in quantities in the upper layers, it may be accepted that the eel is also able to do this; and unless it be considered that the eel migrates as a rule in the upper layers, I do not understand how the surface currents, the wind and the moonlight can have so great an influence on the migrations of the eel as they actually have.

If it is the case that the eel migrates as a rule in the upper layers, we have all the more reason to expect that artificial surface-light (by projectors) can affect their migrations; but for the time being I do not know what happens under greater conditions: the experiment must first be made.

The Biological Station has no rights of eel-trap fishing except over quite a limited area at Oddesund, where the fishermen have rights in the neighbourhood. It seems to me more natural therefore that these experiments in future should likewise be continued by owners of large eel fisheries, who have large tracts of water at their disposal. These owners are undoubtedly warranted in making them.

The light-projector mentioned has a strength of 10,000 power normal light and can be obtained for some few hundred kroner inclusive of the acetylene-holder etc. I should imagine that the experiment would be successful, if made from the outermost pole of the eel-trap, the light being shone obliquely forwards so that it would cause the eels to enter the trap, where they would otherwise pass beyond it; or if the net of the trap is far below the surface of the water, then the projector should be placed on one of the outer poles and the light shone inwards along the trap, so as to hinder the eels from swimming past over the net and its guides. It must be remembered however that such a light-projector may diminish as well as increase the catch in an eel-net or trap, all according as the light is well or badly placed, and that the matter is as yet insufficiently tested. It is only by continued investigations that we shall arrive at the right method of working. That the light-projector may easily prove of advantage in such waters as the mouths of Nissum Fjord and Ringkjøbing Fjord, I consider certain, in spite of the fact that my 1905 experiment at the first place was without result. The light-projector is certainly much easier to handle than the lanterns then used. It is possible that in smaller waters, e. g. Svendborg Sund, the acetylene flare-lanterns common there made do good service. If any one is willing to undertake such experiments I am willing to give them all the information I can, as I must always consider it of advantage for our fisheries, that the methods of catching the migrating eels in this country should be improved as much as possible. We obtain as yet far too little advantage from the quantities of eels which pass through our Belts and the Sound.

That this account is not entirely fanciful is shown amongst other things by the conditions at the opening of the Nissum Fjord into the North Sea (Thorsminde). The outlet (»Mindet«) was closed during the period of the eel-migration in 1906 by the sea throwing up a sand-heap right across it. The eels continued however to stream towards the closed »Minde«; they could clearly detect the sea-water through the sand; and according to notices in the papers there, confirmed by men known to me, ca. 12,000 lb. of eels were fished within a short time.

Before the moonless nights of November came, the »Minde« was again open.

The notice concludes: »What enormous quantities of eels there must be in such a fjord, and what wealth passes during the three moonless periods out from the Lim-Fjord through the Thyborøn Canal into the North Sea, wealth that never returns.«

This is true; we must learn how to stop the eel-migration each year, at Thorsminde as well as in Ringkjøbing Fjord and Lim-Fjord, because it is all a

chance what the sea may do when throwing up sandbanks; and in the Lim-Fjord it is to be hoped this will never occur again.

I may only call to mind here, that even more eels pass through the Sound and the Belts, namely, all the eels from the uplands of the whole Baltic; we must get hold of these also and must not refrain from making experiments even here. The State has brought the matter forward; it is for private persons to help in their own interests. The first experiments would not be expensive.

In addition to the actual light-experiments, the Station has this year made two other experiments in regard to the capture of eels; the one at Oddesund N. where the experiment was made of setting out traps with guides of the same height as the depth of water, that is, they reached from the surface to the bottom, ca. 14—15 feet, as it is my conviction as well as that of many fishermen that most of the eels go over the guides of the traps; otherwise the succeeding traps could not take so many fish as they do.

To judge from this experiment however, there are but few places where the guiding net can be used so high when it is fastened both above and below to the poles, and it is only then that it stands up well, as it becomes readily filled with sea-weed and either the poles fall or are broken and the net ruptured.

In order therefore to catch the eels in the uppermost layers we must have light on the water, — light that does not penetrate too deep down but shines out very obliquely over the water.

When these high guides to the net are too long they have a further disadvantage, namely, that the boats cannot sail over them; even if by depressing the guides at a few places sailing over them is made possible, yet the high guides are a great difficulty.

The second experiment consisted in blockading the whole outlet at Kilen with a small- meshed net during the period of migration, so that no silver eels could escape. I did this in order to learn how large were the quantities of eels which migrated from this water in the course of one autumn.

The silver eels of Kilen are all so small that they could not be taken in the permitted eel-traps; they are therefore lost to the fishery as now carried on. They are almost all male eels and ca. $^1/_6$ of the total weight is under 12 inches — and can thus not be sold.

According to the statement below regarding the catch, 1809 lbs. were taken to a value of 562 Kr. 54 Øre.

The fisherman Thomas Rud looked after the trap for the Station.

It is in high degree unreasonable, that so many eels should yearly be lost to the people; and this year's catch was perhaps not even up to the average. As science has now at last shown, that no damage is done by taking these small eels, all administrative hindrances to their capture should be removed out of the way. Kilen is not the only water in Denmark from which such eels migrate out without being put to use.

Catch of eels at the Kilen outlet, autumn 1906:

August	16.	$4^1/_2$ ℔	eels.
—	25.	28	» »
—	26.	30	» »
September	6.	170	» »
—	13.	$160^1/_2$	» »
—	15.	128	» »
—	17.	437	» »
—	22.	102	» »
—	29.	100	» »
October	7.	205	» »
—	10.	215	» »
—	13.	144	» »
—	25.	85	» »

These data do not indicate the exact days of capture but the dates when the eels taken were put up for sale. The price per ℔ was 30 Øre for the small and 58 Øre for the large eels; ca. 300 ℔ undersized eels were naturally not sold.

After the above was written, it has come to my knowledge that the fishermen, amongst others of Korsør, have begun this year to use stake-nets for the capture of silver eels, that is, a kind of apparatus with high guiding net; they are said to have had very good results. It is not the first time that such apparatus has been used in Denmark for the fishing of silver eels; but it is quite possible that the discussion about the experiments to stop the eels made by the Biological Station, and the idea that these migrate up in the water, have induced several fishermen to make experiments in this direction with high guides; these experiments have come to my knowledge from several places just this year (1906) — places where they were not made before. I mention this because it is perhaps an example of how ideas can travel without one knowing exactly how they manage to spread about. So much at any rate is certain that the Station's experiments on eel-fishing have interested the fishermen extremely; I can only hope that the use of the light will also soon be taken up seriously by them. It will not be the first time that the Station has attained good results by cooperating with the fishermen; and if this is only attained, it is quite unessential whether the Station succeeds in carrying out the matter thoroughly or the fishermen do so.

Age and Rate of Growth of the Eel

by

K. J. Gemzøe,
Assistant at the Biological Station.

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It is not by chance that the Biological Station happens to be engaged just at the present time with investigations into the biology of the eel, and that at the request of the Director I now publish the following contribution towards the elucidation of its natural history, based on the cruise of the »Sallingsund« in 1906, since, so long as every one was confused and uncertain as to the reproduction of the eel, not even knowing where its spawning places were to be found, and the possibility indeed could not be excluded that it spawned in freshwater, though all probability spoke against this — so long as these primary questions remained unanswered, it was difficult to think of making detailed investigations on the more secondary questions such as the growth and age of the eel.

The biological investigations of recent years had, however, removed the obscurity which had previously covered the question of the eel, so that the time had come for making the above-mentioned more detailed investigations.

It will perhaps be of interest to give here quite briefly a summary of the investigations of the last ten years.

The question of the reproduction of the eel awakened considerable interest even in olden times. Thus, Aristotle occupied himself with it and concluded that it was a *generatio æquivoca* — that the eel arose from the mud on the bottom of the sea. But in spite of this early notice, two thousand years elapsed before anything essential appeared to throw light upon the obscure subject; not that many diverse things were not written during this long period concerning such an economically important fish, but they were of no interest. Thus, Blanchard in his book: »Les poissons des eaux douces de la France«, says, »The views formulated and the treatises written concerning the reproduction of the eel are quite innumerable and quite devoid of interest as actual observations are wanting.« It is only within the most recent times that clearness has come, thanks to Italian and Danish investigators.

In the year 1893 Grassi and Calandruccio succeeded in showing that *Leptocephalus brevirostris*, which had long been known in the Mediterranean but had always offered some difficulty relative to its position in classification, was a young stage in the development of the common eel; they observed how it gradually assumed the well known form of the eel. It was thus proved that the eel living in South Europe, which is quite the same species as our own, spawns out in the deep water of the Mediterranean. It was improbable, however, that the eel, which lives in the fresh and salt waters of Northern Europe, should migrate to the Mediterranean in order to spawn. It had certainly become gradually known that the northern eels after a space of time, the length of which was not known, left these waters and migrated away — where was also not known. And it was clearly shown by C. G. Joh. Petersen in 1895 that before their departure they assumed a special breeding-dress, changing from yellow to silver, so that this together with the relatively greater development of the sexual organs indicated a spawning migration.

It was also well-known that in the spring countless quantities of young eels came to our waters, so that the eel must have spawned at one place or another — but where? It was only when the international investigations had extended their sphere of operations to the waters of the Atlantic bordering on

North Europe, that the solution of the problem was arrived at. In the month of May 1904 Dr. Johs. Schmidt found the first specimen of *Leptocephalus brevirostris* pelagically in the ocean S. W. of the Færoes, and in the following year was successful in proving their presence in quantities in the deep Atlantic waters, West and especially S. W. of Ireland. (See C. G. Joh. Petersen: Larval eels *(Leptocephalus brevirostris)* of the Atlantic coasts of Europe. Særtryk af Meddelelser fra Kommissionen for Havundersøgelser. Serie: Fiskeri, Bind I, 1905; and also, Johs. Schmidt: Contributions to the life-history of the eel (*Anguilla vulgaris,* Flem.) 1906).

Thus the spawning place of the eel was found; we know where the silver eels are going to when they leave our fresh and salt water in autumn, and we know whence the countless swarms of montée (elvers or glass-eels) come which appear on our coasts in spring.

The question still remains whether the eels there lay eggs or are viviparous. This has not yet been answered directly but the great probability is that the eel lays eggs; the structure of its ovary with the enormous number of eggs speaks in favour of this.

The silver eel does not return from its spawning place — probably it dies immediately after its first spawning period. — —

As can be seen from this brief summary, the main features in the life-history of the eel are quite well known. Twice during its life it actually undertakes the long migrations from and to the Atlantic Ocean, and though it is difficult to understand how such tiny creatures as the small elvers (montée) can traverse such a great distance as is here in question, yet it is nevertheless a fact.

In the intervening period between these migrations, elver-migration and spawning-migration, the eels live in fresh water or in the sea in shallow water; during this period they feed and grow and may not be regarded as the adult fish before it assumes its breeding-dress; then it ceases to take food and migrates out towards its spawning place.

How great is the period, how many years lie between the two great migrations of the eel?

How old are the silver eels when they leave these waters as adults?

This is a question which has great importance for all interested in the eel-fisheries; and their number is very large, not least in Denmark. It is indeed a well-known thing that eels occur in our freshwater and in the waters of little depth around our coast in very great numbers, especially where the bottom in the latter case is covered with zostera — the eel-grass, as it is generally called by the fishermen. The eel-fishery is carried on with the most different kinds of apparatus throughout the year; there is no cessation as is the case in our other fisheries. A sketch of how it is carried on in one of our larger fjords is given by C. G. Joh. Petersen in the Report of the Biological Station, I. 1890—(91). This gives an idea of the intensity with which it proceeds, and one can understand that great economic interests are bound up in it. The question of the growth and age of the

eel can therefore reckon upon rousing great interest, not least in this country, all the more because trustworthy information on the matter is lacking.

There is certainly no lack of views on this subject — but they must be regarded as pure guesses and hardly rest upon actual observations. Thus A. Feddersen in a little popular work (»Aalefaringen«, Kjøbenhavn 1904) states that it is generally considered, that the young eel one year after its arrival (the elver he calls »aalefaring«) is 20 cm. long (8 inches), without showing so far as can be seen whether he shares this opinion, nor what reasons there are for it. In the same work further, he writes that »the Swede Norbäck is of opinion that the eel grows about 4 inches in length each year; according to his view it is 6—8 inches long in the first autumn, 12—14 inches in the second, 18—20 in the third and at this length weighs 1—1$^1/_2$ ℔. A six year old eel is said to be 2.5—3 feet long, 1$^1/_2$—2 inches thick and weighs 5—6 ℔.« And Feddersen states that »the French pisciculturists have a slightly different scale for the growth: in the second year ca. 14—15 inches and after the fourth year the eel is said not to grow.« He adds however, that »these data do not suit all waters« and is of opinion »that the growth of the elvers is naturally like that of other fishes, according to the nutriment-qualities of the water in which they take up their abode to grow.«

I have mentioned these extremely different data on the growth, in order to show how contradictory they are and how little one really knows about the question. It is obvious that the difficult path of observation has not been traversed, nor have the necessary materials been collected nor the methods used which are at our disposal for the determination of the age and growth of fishes.

Even this side of the matter, to obtain the necessary material, i.e. a sufficient number of specimens at all sizes, has its difficulty. It is naturally quite easy to procure eels of the sizes the fishermen take in their nets and traps; but special apparatus is necessary for the capture of all the undersized eels (those that do not reach the smallest size permitted in Denmark: 11 inches to the root of the tail = ca. 31.5 cm. to the end of the caudal fin); a small meshed net is the best for the capture of eels of ca. 20—30 cm., whilst the smaller under ca. 20 cm. can scarcely be taken with any other apparatus than shrimp-nets, which must be very fine-meshed or covered with bobinet-cloth; as the latter does not allow even the smallest to pass through. The shrimp shove-net can naturally only be used in shallow water where one can wade; but under favourable conditions (see later) it can take the small eels in quantities. It appears from the methods of capture thus described, that it is difficult or impossible to procure a sufficient number of eels of all sizes from the same place, so that it is not possible to draw up a table showing all the yeargroups on the basis of material from a single locality; to get a sufficient number of the eels ca. 20—ca. 30 cm. is especially difficult, as the tables show; comparatively few of this size are noted in them.

If C. G. Joh. Petersen's method by measurements were the only available one for the determination of the growth and age of the eel, this circumstance would have an unfortunate influence. However excellent the method may be for the determination of the age of the small eels — and there it is quite indispensable — it cannot be used for the age-determination of eels over ca. 18—20 cm., partly because of the difficulties of capture, partly because the larger eels cannot

be divided into groups; they form on the contrary one large group, obviously including several yeargroups which must be separated by other methods, if such can be obtained.

There is fortunately another method, whose usefulness for the determination of the age of the eel will, it is hoped, be clearly shown by the data given in the present paper.

This is based on using the concentric zones or rings in the scales of the eel for determining the age; because these are annual rings and by counting their number and then adding 2 to the number found we ascertain how many years the specimen investigated has lived in our waters. — As O-point I take not the date of hatching but the date of immigration, that is, the time when it reached our coasts as elver (montée), and thus do not include the period passed as Leptocephalus out in the Atlantic. As the date of immigration falls in the spring and may with approximate accuracy be placed at May 1st., it is naturally only for this date quite correct to add the number 2 — otherwise we have to remember to return to the O-point. The number 2 must be added, because the eel lives 2 years in our waters before it takes on scales.

To be able to appreciate the grounds on which the hypothesis framed rests, an exact knowledge of the structure of the scales of the eel, their anatomy, is necessary; and as the scales are not formed in the eel all at the same time, it is advisable likewise to know something of the scaly covering of the fish as a whole. The two following sections are devoted to these questions.

Structure of the scales of the eel.

In the Archives de Zoologie expérimentale et générale, Tome deuxième, Paris 1873, a treatrise is published by M. E. Baudelot: Recherches sur la structure et le développement des écailles des poissons osseux, in which a description based on careful investigation is given of the scales of several fishes, amongst them of the eel. As Baudelot shows himself in this to be a specially fine observer and presents his observations in a clear and well-arranged manner, I may give citations from his work, which so far as my own investigations go I am able to fully substantiate.

First of all, Baudelot describes briefly the situation of the scales in the skin of the eel and their different size in different specimens, on which he remarks: »The dimensions of the scales show variations, which — with all due reservation — are so distinct, that they might seen to be dependent upon the age of the fish.« In an eel of 60—70 cm. in length a certain number of scales, 2 to 3 mm. in length and about 1 mm. in breadth, were measured.

Then he passes to an investigation and description of the scales of the eel. »With a magnification of about 30 diameters, an isolated scale appears as a small transparent plate, the whole surface of which is divided into a number of small round or oval plates, which are very sharply defined, juxtaposed and arranged in rows more or less parallel to the outer contour of the scale. The plates mentioned, which appear light against the darker ground of the scale, have been considered by some naturalists, e. g. Owen, as hollows or holes in the structure

(composition) of the scale; we shall see later that on the contrary they are plates, which stand out in very obvious relief on the surface of a continuous, fibrous plate which forms the substratum of the scale.

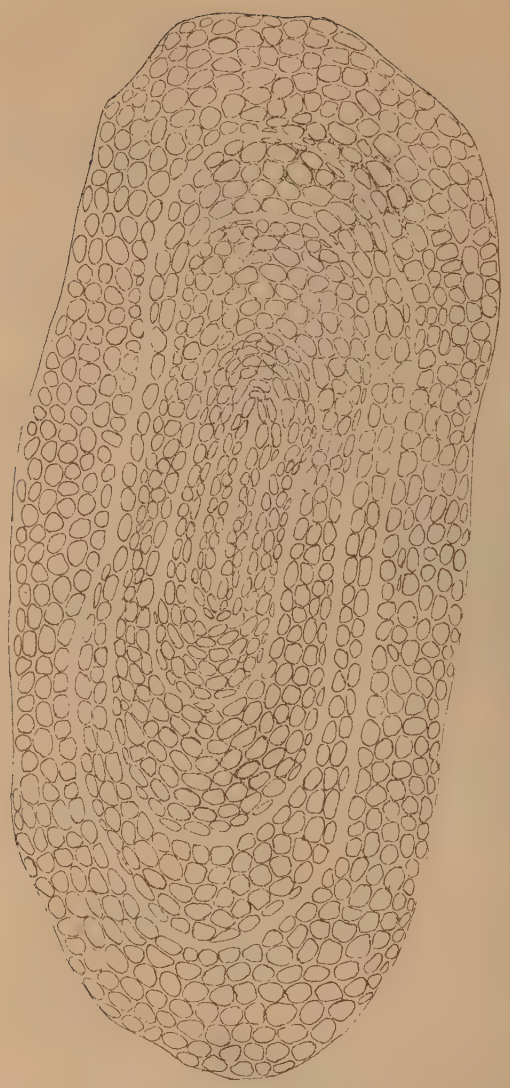
»To obtain a clear impression of the structure of the skeleton, we must study it under a magnification of 100—400 diameters. Placing a scale under the microscope and examining each of its surfaces, it is easy to determine that the two surfaces have a characteristic and quite different appearance. — The inner surface is completely smooth; the outer on the other hand is covered with round calcareous plates resembling small medallions, which stand up very distinctly from the fibrous ground-substance of the scale. The number of these plates on a scale of 2 mm. in length is at least one thousand.«

B. then examines the two surfaces separately beginning with the outer. He first studies the medallion-like plates. He finds that they vary greatly in form and considers that »we can scarcely say more in general than that they show rounded contours; some are circular, most have the form of a more or less elongated ellipse, which is sometimes irregular.« After briefly describing several of these forms B. enquires what these plate-like bodies really are and writes: »Each plate may in regard to its thickness be considered as a sort of very flat cylinder with two parallel end-surfaces, an inner which is connected with the fibrous ground-substance of the scale, and an outer which projects freely. The height of the cylinder (or thickness of the plate) is ca. 4 to 6 hundredth-parts of a millimeter. The outer end-surface has a plain, quite flat surface definitely bounded as to its circumference, which makes each plate resemble a small looking-glass surrounded by a frame of dark colour. The fact that this outer end-surface allows the light to pass through it and throw a light-reflexion on the fibrous ground-substance of the scale has given rise to a peculiar optic illusion; as I have already mentioned, it has been taken by several observers to be holes bored in the structure of the scale.

»The inner end-surface of the plate rests on the fibrous ground-substance of the scale and is fused with it. It is a little broader than the outer, and whereas the latter shows a gently rounded contour, this in the former is usually more irregular with more or less distinct balls of calcareous substance in its length. Sometimes the inner end-surface is broadened and expanded into a fine lamella with indented contours on the underlying ground-substance.«

B. next describes the foliate structure of these cylinders and continues with a detailed account of how they are arranged on the surface of the scale. — »The calcareous plates do not touch one another; between them is a larger or smaller interspace in which is seen the fibrous structure of the scale.

»Taken as a whole, the plates are arranged in rows which are more or less regular and parallel to the margin of the scale. In each row their longest diameter follows the longitudinal axis of the row itself. Not all rows traverse the whole surface of the scale; some disappear after a longer or shorter course and seem to lose themselves amongst the adjacent rows, as can be easily settled by counting the rows along and across a scale; in the first direction there are more than in the latter.«



Chr. D. Lunn ad naturam del. × 70.

Fig. 1. Scale of a female eel taken in the Sound, December 1906. The scale shows 5 annual rings (central zone + 4 concentric zones) and was thus laid down in the summer of 1902; the eel consequently had arrived in the spring of 1900 as glass-eel and was thus 7 years old, counting from the date of immigration (more exactly, 6 years and 7 months).
It is very clearly seen that the annual ring for 1906 is completely formed.

Then B. mentions the peculiar concentric rings or zones in the scales of the eel — what I have above called the annual rings. His words are as follows:

»The plates are not only arranged in longitudinal rows; they show also another grouping which I consider worthy of attention. In place of being distributed in the same way over the whole surface of the scale, they usually form various concentric zones, which are mutually separated more or less distinctly by an interspace, which is occupied by the fibrous substratum of the scale. There are in general 3 to 4 of these concentric rings on a scale of 2 to 3 mm. in length. — When the central zone is well isolated, it gives one the impression of being a small scale brought into the centre of a larger scale. These perhaps represent zones of growth. However this may be, the calcareous plates found along the outer margin of each zone usually give one the impression of being quite rudimentary; they are smaller, very narrow, sometimes indeed reduced to a level and straight comb. The plates in the central zone are in general smaller than those found in the zones further out towards the periphery of the scale. In the median part of the central zone there is usually a larger or smaller empty space consisting of the scale's fibrous ground-substance, which is overstrewn with single or in various ways aggregated, calcareous grains.

»The membranous plate which forms the substratum of the calcareous plates is formed of connective tissue, the fibres of which are arranged more or less parallel to the margin of the scale. To be able to see these fibres exactly the inner surface of the scale must be examined under a high power. Treated with a concentrated solution of warm potash, the connected tissue is dissolved and

leaves as deposit some fine threads of organic substance, in which some very small calcareous grains are seen.«

Lastly, B. mentions that the scale of the eel develops late; he has not found any on an eel of 7 cm. in length. And he concludes his description of the scales of the eel by saying, that they are specially well adapted to the study of the development of the scale. He lacked the material at that time but hoped to procure it later.

To this description by Baudelot I may add some remarks on the concentric zones. One might think, for example, that they always had the same breadth in the same scale, but this is not the case; the number of rows of small plates (medallions) within the different zones varies greatly. — Nor can these always be correctly described by the term rings. Sometimes the zone is only developed as a kind of cap at both ends of the scale's longitudinal axis, so that nothing of this zone appears in the scale's transverse axis. The probability is that in these cases we have to do with a restricted formation for the year; the specimen has not succeeded in forming any connection between the two caps, before the period of growth ended. This is indicated especially by the fact, that in the silver eel we often find the outermost ring represented by these two caps, which I have also seen in formation and growth; and in this the growth of the scale ceases earlier in summer than in the yellow eel, so that there is actually less time for the formation of rings — which results therefore in their incompleteness. — But this imperfect ring-formation may also often occur within the scale between other fully developed rings. In accordance with what has been said above, they must always be included in determining the age of the scale (and of the eel).

The scaly covering of the eel (by Chr. D. Lunn).

The appearance of the scaly covering in the eel is very variable in the different specimens and varies constantly with the age of the individual. Even if most of the scales are laid down at the same time (in the same summer), this rule is far from being without exceptions.

I choose for description here a single specimen which I consider to be typical, and take therefore an »8 years« old, female eel (the oldest scale has 6 annual rings).

On a broad belt above and below the lateral line the long, narrow scales lie in two directions at right-angles to one another, forming quite short rows, in which the scales lie parallel to one another; as the rows form angles of 90° with one another, this part of the skin has a peculiar, chequered appearance. Almost all the scales are here of the same age (all show 6 annual rings), but we find exceptionally smaller and younger scales in the outermost of the rows mentioned, which in general contain 6—10 scales (rarely up to 18—20). — Ventrally the scales lie only in one direction, and the nearer we approach the ventral margin the more is this direction parallel to the longitudinal axis of the fish; here the scales are also younger (4—6 annual rings, some even fewer). Dorsally the scales also decrease in age, the scales in the outermost part of the belt mentioned (and

in a narrow stripe on the part of the back lying between the postoccipital region and the dorsal fin) lying on both sides of the dorsal fin parallel to one another, just as on the ventral aspect, and up towards the dorsal fin they become more parallel to this. All the scales in this part have almost the same number of annual rings (1—2), but are of the same size as the 6-year old scales along the lateral line. These scales are obviously laid down in the 4th and 5th years, when the eel increases very greatly in weight, whilst the growth in length is relatively much less than in the foregoing 2—3 years; this means that a great increase in thickness occurs at this time, resulting in the formation of a naked (scaleless) part along the back.

The condition thus described holds for the longest part of the eel's body; towards the head and the tail there are smaller and younger scales. In the 8-year old individual described here, which was 65 cm. long, the scales along the lateral line even 15 cm. from the end of the tail had 3—4 annual rings (at the root of the dorsal fin 2—4), and at the end of the tail 2—3 rings. On the back anteriorly the scales between the pectorals had 3—4 annual rings, those on the head between the eyes 2—3 annual rings, and extremely small scales with 1—2 annual rings were found immediately behind the anterior nasal openings; 1—2-year rings were also found on the »cheeks« of the head. On the other hand, the snout, the labial fold of the upper jaw, the under jaw and all the part between its corners, also the »throat« (the first part of the belly) are scaleless.

I have not been able to find scales on the pectorals, on the other hand the dorsal fin is covered with scales almost right out to its free margin; on the proximal part the scales have 2—3 annual rings, nearer the edge only 1; the scales on the dorsal fin are more irregularly distributed than on the body.

On the anal fin there are quite few scales (1—2 years), whereas on the caudal fin — meaning thereby the portion of the vertical fin whose rays are attached round the last 3 vertebræ of the vertebral column — there are no scales.

In specimens of the same size I am able with a little practice to distinguish easily the males from the females by examining the scales macroscopically, the scales of the male (with more annual rings) being relatively much broader than those of the female.

Within the group Anguillinæ (Günther), which includes the genera Anguilla, Conger, Congromuræna and Uroconger, Anguilla is the only one that has scales; these Günther calls rudimentary; they are certainly feeble, but of so connected and fine a structure that the description is not very applicable. We might perhaps with more right call the scaly covering in its entirety rudimentary, as the scales lie very deep in the skin and are only adnate, not covering one another with overhanging margins; the very large, uncovered parts of skin between the scales point in the same direction; these are indeed so large that there is often easily room for a scale there.

Are the concentric zones (rings) in the scale of the eel to be considered as annual rings?

The idea that periodicity in the growth of a fish should be so impressed on the structure of the scales, that we might be able at once to read on them how many periods or in other words: how many years the specimen examined has lived — is not new. That this method has been used for the determination of the age of the carp is well-known (see the papers by Hoffbauer: Die Altersbestimmung des Karpfen an seiner Schuppe. Jahresbericht des Schlesischen Fischerei-Vereins 1899; and Weitere Beiträge zur Bestimmung des Alters und Wachstumsverlaufes an der Struktur der Fischschuppe. Jahresbericht der teichwirthschaftlichen Versuch-Station zu Trachenberg. 1901). — It has also been used however for age-determination on other fishes, for example, herring and gadoids. J. Stuart Thomson has published a paper: The periodic growth of Scales in Gadidæ as an Index of Age (in Vol. VII, No. 1 of the Journal of the Marine Biological Association of the United Kingdom, Plymouth 1904), in which he shows the annual rings in the scales of several gadoids and comes to the following result with regard to the practicability of the method: »After an investigation of thousands of scales from these gadoids, I hold that in 98 cases out of 100 one would arrive at a very closely approximate idea of the age of the fish from an examination of 3 or 4 well-developed scales taken from the median region of the flanks near the lateral line.« This sentence may also be extended to include the scales of even the cod *(Gadus callarias L.),* and presumably this is also Stuart Thomson's meaning, though he has only examined a few of them. More detailed investigations on this matter were however undertaken by the Dane, Chr. D. Lunn, during a stay at the Bergen Museum in 1905; as these are not yet published and I have had the opportunity through the kindness of the author to ascertain the results, I shall only mention that L. has found the annual rings very distinct and well-developed on the scales of the cod from Norwegian waters. They are less distinct on the scales of the cod from our own waters. — It would lead too far afield to enter here upon a detailed account of the scales of the cod. So much only may be said, that the numerous small plates (scalelets) into which the surface is divided are arranged in radial rows and have a very variable lumen; this causes the appearance of concentric rings, as in the radial rows many small plates with broad lumina alternate with a few in which the lumina are much narrower. The investigations mentioned have now shown that the wide and broad, small plates are formed in summer, are summer-rings, and that the contracted and narrower are formed in autumn (and winter), are winter-rings, so that the annual ring consists of many small plates with wide lumina and few with narrow; as the latter are formed last, the boundary between two annual rings is seen very distinctly.

This condition will remind the reader of the concentric zones in the scales of the eel, as mentioned in describing the latter; in these also there is a difference in each zone between broad small-plates in the inner, first-formed part and narrower small-plates out towards the margin. — That the zones in the scale of the eel are even more distinctly marked off, in that the ground-substance of the scale is

apparent outside all the medallions in the zone and thus forms a framework round them and that this ground-substance, when several zones occur in a scale, comes to form as if passages, all more or less mutually parallel and forming abrupt and distinct boundaries between the single zones or rings — is something new, but serves only to make the rings even more distinct. — It is evident that there is a resemblance between the structure of the gadoid scale and the eel scale, and if it is certain that the concentric zones in the former are annual rings, it is undeniably most reasonable to consider that the same holds good in the latter.

This view harmonises exceedingly well also with what we know of the life and growth of the eel. It is well-known that the eel passes the cold part of the year down at the bottom in a kind of resting-stage; as also that it scarcely feeds during this period and its functions and vitality are lowered and reduced. In

Table 1.

	Brook at Frederikshavn.	Kattegat.
cm.	18. October 1904	28. March 1905
30	59 spec.; all pig	102 spec.; much
29	mented.	pigmented; at
28		least one year
27		older than the
26		elvers.
25		
24		
23		
22		
21		
20		
19		
18		
17		
16		
15,5		2 spec.
15	1 spec.	
14	2 »	
13		2 »
12	3 »	2 »
11,5		4 »
11	6 »	5 »
10,5		3 »
10	4 »	6 »
9,5		5 »
9	7 »	12 »
8,5	19 »	31 »
8		15 »
7,5	15 »	15 »
7		1 »
6,5	2 »	
6		
5		
4		
3		
2		
1		

Table 2.

	a. Audebo. Lamme Fjord. Shrimp shove-net with bobinet.	b. In Kilen at Struer. Shrimp shove-net with bobinet.	c. Seden Strand. Odense Fjord. Shrimp shove-net with bobinet.
cm.	14—15 May 1906.	10. Septbr. 1906.	31. May 1906.
30			
29			
28			2 spec.
27			2 »
26			4 »
25			2 »
24		1 spec.	14 »
23		1 »	11 »
22			21 » III group
21		1 »	8 »
20		1 »	10 »
19		2 »	6 »
18	1 spec.	1 »	8 »
17	1 »	3 »	15 »
16		6 »	10 »
15	3 »	7 »	18 »
14	3 »	15 »	30 »
13		31 »	25 »
12	1 »	42 » I group	37 » II group
11	5 »	44 »	40 »
10	14 »	26 »	17 »
9	116 »	56 »	11 »
8	161 » I group	65 » 0 group	1 » [I group]
7	44 » 0 group	6 »	2 » [0 group]
6	Quantity of elvers of		
5	64—77 mm.		
4			
3			
2			
1			

other words the life of the eel is marked by an extreme periodicity, much stronger than that in the fishes, the scales of which have been mentioned above. We can already conclude from what has been said, that the growth of the eel in this resting period either ceases entirely or is in any case extremely small. This is shown directly by a comparison of the eels taken in autumn and in the following spring, before growth has recommenced (see Tables 1 and 2). Table 1 has been taken from the above-mentioned paper by A. C. Johansen. Table 2 and all following Tables are based on the investigations of the Biological Station in the summer of 1906. It is seen at once from Tab. 1 that the group (year-group) which has its maximum at 8 cm. is found both in autumn and early in the following spring; the eels of this group have not grown in the course of the winter; and the conditions will be the same for the individuals of the other year-groups. This is also seen indirectly from Table 2. The I. group (with maximum at 11—12 cm.) in column 2 (autumn) is met with in spring at the same size (column 3); it can scarcely cause any error if it is now called the II. group. — For the rest, see the following description with regard to the »groups«.

The possibility is thus present, that not only the growth of the eel itself but also, for example, the growth of its scales is marked by this periodicity; it is indeed not improbable that the stoppage in growth also indicates a stoppage in the growth of the scales, which is expressed in their structure — and what has been said above on the matter indicates further that this is really the case.

We have seen (p. 14) that Baudelot had already suspected a connection between the size of the scales and the size of the eels and states: »The dimensions of the scale show variations which — with all due reservation — are so distinct that they might seem to be dependent upon the age of the fish.« And in describing the zones of the scales he says quite *en passant*: »The zones perhaps represent zones of growth«, but he does not inquire further into this question.

Independent of Baudelot, C. G. Joh. Petersen also mentioned the matter and expressed clearly the idea, that the zones, which he called growth-streaks, were possibly to be considered annual rings. In the Report of the Biological Station, V. 1894, this author writes: »About this length, ca. 200 mm., the eels begin to have scales, previously they are naked. The scales appear first near the lateral line, they are somewhat elongated and show growth-streaks, which possibly correspond in number fairly exactly to the years passed; this is a matter however which requires further investigation.« — Finally, there is a statement by Stuart Thomson who briefly mentions the scales of the eel in his above-mentioned paper. He says: »The scales of the eel show rings very clearly; but whether these are annual or not I would not at present certainly determine, as I have not a complete series of the fish. If the rings are annual, and from the fact that these animals seem to have a winter sleep, it would be natural to suppose that such is the case — then . . . .«

That this idea is correct, that it is not only possible and probable but in full agreement with the actual conditions, will be proved here. And the proof consists in following the development and growth of the scales throughout a period of growth. If we examine eels which measure 18 cm. or more in length in the autumn, we find scales in their skin. In specimens of 18—20 cm. in length, there are often very few scales; sometimes they form only a row above and along the lateral line on the central part of the fish, it happens even that not so many are formed as to form a continuous row. The scales do not show concentric zones or rings; there is only a small, oval, plate-like body which however has quite the structure described above (the surface is divided into small medallions etc.) We may call this the central zone or only the centre. — It is characteristic of the scales at this period of the year, that the outermost row of the medallions is also quite surrounded by the margin of the underlying plate, so that this is seen as a contour or frame, everywhere very distinct, outside all the small plates; it is the more apparent as it is marked by a much darker colour than these. — The small plates or medallions have distinct and sharp contours, and decrease in size out towards the margin of the scale. The whole has a firm, solid and finished appearance. — In May we again take up the investigation and on eels of the size mentioned above we find scales with quite the same appearance. The growth of the scale has thus not yet begun, which indeed was to be expected, as the eel itself has not yet begun to grow; see Tab. 1—2. — This is the condition in May and partly in June; yet at the end of this month I have observed some scales which had undoubtedly begun to form a concentric zone outside the central zone; and from the middle of July the newly formed zone takes on a considerable breadth and is now found on practically all the scales investigated. — In longer eels whose scales in spring show one to several zones outside the central zone, the condition is quite the same. It is thus noted in the Journal for July 17th, that the annual rings on many of the scales from the summer of 1906 seem almost completed. The annual rings seem thus to grow very quickly. — Table 3

Table 3.

At Struer. Shrimp shove-net with bobinet.

17th August 1906.

cm.	A.	B.	C.	D.
25				
24	2? 2?		x x	
23	1		x	
22	1 1 1		x x	x
21	1 1 1 1 1 1 1 1	x	x x x x x x	
20	0 1 1 1 1 1 1 1 1 1	x	x x x x x	x x
19	1 1 1	x	x x	
18	0 1	x		
17	0 0			
16	0 0 0 0 1 1	x x		
15	0 0 0 0			
14	0			
13	0 0			
12				
11				
10				

gives a view of the growth of the annual rings in the scales of eels taken at Struer on the 17th of August. In column A all the specimens examined are noted; 0 means that the specimens had no scales, 1, 2 etc. that scales were found and that these showed the central zone only or this + one to several concentric zones. (In the following Tables also, the numbers do not indicate the age of the specimen but of its scales; the central zone is always taken as the 1st annual ring). In the columns B, C and D in Tab. 3 are represented the eels of column A which had scales, arranged so that the crosses in B represent the specimens in which all the scales examined were in process of growth, and those in D the specimens in which growth of the scales had ceased; lastly, column C represents the eels in which the scales were growing equally or had ceased to grow. — Thus the annual rings were already on August 17th quite completely formed in some and were nearly so in the majority. — Table 4 shows how far on the scales in larger eels were in their growth at the same period; we notice that in the silver eels they are

Table 4.

In the outlet at Struer.

Hand-net. 17th August 1906.

cm.	silver.	half silver.	yellow.
42			
41			
40			
39			
38			
37	x		
36	x x	o o o	x
35	x x x	x	o o o
34	x x x	⊗	x o
33			o o o
32	x x	⊗	o
31			x o o o
30			x o o
29			x x o o o
28			x
27			
26			
25			o
24			
23			x
22			
21			
20			

x = growth of scale concluded.
o = » » not concluded.
⊗ = » » partly » , i.e. some of those investigated still growing

completed much earlier than in the yellow eels. But even in the latter growth is not for long, as we can scarcely find any eels in which the scales are still growing towards the end of September; thus the new annual ring is completely formed at the time the cold period of the year sets in.

If one only becomes familiar with the structure of the scales and their whole appearance, it is extremely easy to see in them whether they are growing or not. As mentioned above the underlying surface is seen in the latter as a distinct contour or frame around the outermost row of small plates; the latter likewise decrease

in size out towards the margin of the scale (or zone) and have sharply defined contours. — If on the other hand the scale is growing the outer border is quite wanting; the small plates extend out to the margin of the scale which has thus an irregular form, the more so as their contour is often of quite a different appearance from that of the completed scale. They are rarely sharply defined, as a rule more or less projecting, and the one margin — the outer — is quite wanting, so that in appearance they are u-shaped, and thus agree with what Baudelot says of the calcareous plates found along the outer margin of the zone; »they often show quite a rudimentary appearance; they are sometimes reduced to a comb pure and simple.« This just suits the appearance of the still incomplete calcareous plates; and it is reasonable to suppose that among the scales Baudelot examined were some still growing, without his being aware however that this was the reason for their peculiar appearance. — At the same time the whole of the scale has a less transparent, yellowish shimmer over it and a looser structure; this may arise from the circumstance that the ground-substance itself, into which the small plates are fixed by their lower end-surfaces, has not yet attained the firmness and thickness, which the whole period of growth gives. — Lastly, the small plates do not decrease in size towards the margin, so long as only a single or a few rows are laid down.

We come finally to the questions — when are the scales first laid down and where are they first found. The latter may be answered by saying, that the scales first appear along the upper margin of the lateral line, some distance in front of a line drawn from this perpendicularly through the anus; they are laid down on both sides of this line, towards the head and towards the tail and likewise up on the sides of the fish. The scales along the lower border of the lateral line may be laid down at about the same time as those above or somewhat later, and here also the development of the scales in the skin progresses in the same manner as above the lateral line. Sometimes so few are formed in the summer in which the first scales are laid down, that a continuous row even does not occur along the lateral line, but only a few isolated scales are seen here and there. The rule is, however, that several to many rows are formed. — In determining the age, care must naturally be taken to obtain the oldest scales, and one should therefore select the scales at the lateral line somewhat in front of the anus.

»At about this length, ca. 200 mm., the eel begins to have scales« was written by C. G. Joh. Petersen in the Report previously cited (V. 1894). This is certainly somewhat too high; as a general rule we might say: there are completely formed scales in eels of 18 cm. or over. This does not exclude the possibility of finding scaleless eels of 18, 19 and very rarely of 20cm.; and on the other hand, we may find scales in smaller eels, of 17 and extremely rarely 16 cm. — but this as a rule is in summer; the scales are then growing and before growth is concluded the eel will have reached the size of 18 cm. — This size thus represents a limit, scale-limit, which divides the eels into 2 great portions: the naked and the scaled. When the eels during their growth pass this limit — or perhaps even a little before — they begin to have scales. — At what period during growth does this occur? Though I have searched a great deal I have not been able to find scales »in

process of forming« before the first half of June; among a number of eels taken at Struer on June 18th there was a single specimen with the scales just forming; it measured 18 cm.; the central zone was still far from being completely formed, as only a few rows of small plates were completed. As other investigations and work claimed the time between the 1st of July and middle of August, we only once had the opportunity of obtaining small eels; but just at that time on July 11th I found an eel of $18^1/_2$ cm. long in Faxe river in which the scales must have been laid down about that time; so few small plates namely were present that they did not form even a continuous row; nothing else was seen of the scale.

When the investigations were again taken up in August, it was found that scale-formation was far advanced; this will be seen from the earlier used Table 3; all the specimens marked 1 have assumed their scales in the summer of 1906, so that only a central zone was present. The explanation to the Table already given shows that the growth of the central zone had already ceased in some. And the growth of the new as of the older scales is always ended towards the end of September.

This ought to be sufficient proof that a zone, either the central zone itself or a concentric zone, is formed in the scales of the eel in the course of a growth-period extending over some months. I use the term annual ring for these as it seems to me more practical than »summer-ring«, though the latter is really the more correct.

With the aid of these two methods: the measurement-method, which is used firstly on the eels under the scale-limit, and the method of investigating the scales, the work has been carried on to determine the growth of the eel and to determine how long they remain in our waters before they are again on the way back to where they came from as tiny fry.

We may now examine more closely the whole growth-period of the eel, following it from the moment when it appears as elver on our coasts until it again leaves them as adult silver eel.

0-Group (= 1st year's group).

It has long been known, that small eels — about 70 mm. in length — wander into our waters in great quantities in spring and early summer. They have been observed even before they reached into the coasts; thus A. C. Johansen has found them pelagically in the North Sea and Skager Rak in March and April 1905 and says on this in his above-mentioned paper: »the young metamorphosed glass-eels are pelagic in the sea at night, whilst in the day-time they remain at the bottom.« And C. G. Joh. Petersen has likewise taken them pelagically at night in the bay near Kærteminde in April 1905. But they are only seen in large quantities when they have reached the coasts, and especially during their migration up into the rivers; as they are then forced together within a narrow area especially where a barricade, for example at mills, obliges them to stop for a time until they find a way forward.

When these immigrating eels, elvers or »Aalefaring« as A. Feddersen very happily calls them, come to the different coastal tracts of Denmark, cannot at present be determined; the time of immigration may in general be placed in the months of March to June, and is certainly earlier on the west coast of Jutland than in eastern Denmark; but in May 1906 I found them in great quantities in Ribe River and in the river-outlets into the Great Belt and Isse Fjord, and in the first days of June on the coasts of the Smaaland sea.

When the elvers arrive at our coasts, they have a very characteristic appearance, which differs considerably from that of the older eels. The form of the body is quite the same, but the colour is quite different. In these post-larval eels the pigmentation is restricted to the top of the head, the end of the tail and as a rule to two dark streaks below on the sides of the fish, whilst the body is otherwise glass-clear and transparent, so that the vertebral column, the heart and the alimentary canal are seen distinctly. On the belly the yellowish brown colour is quite lacking which is so characteristic of the older eels and is due to the deposit of guanin crystals in the peritoneum; this therefore has not yet taken place. This is in fact the most distinctive mark of the glass-eels, as they are called, as it remains long after the pigment on the back and the sides has so far developed that these take on the well-known colour of the eel.

If we wish therefore to define the term »glass-eel«, the definition would be: eels with colourless, glass-clear belly through which the alimentary canal is distinctly seen because guanin crystals do not occur as yet in the peritoneum.

Towards the summer however this mark of recognition also disappears; it will then be as a rule only by means of their small size and especially their small thickness that specimens of the the 0-group can be distinguished from those of the following year's group.

All the glass-eels which stream to our coasts in spring do not succeed in gaining the fresh water. They seem indeed to have the ability to detect the fresh water, which streams out into the sea and mixes with it near the outlets of the rivers; at these one can find quantities of them hidden under stones, vegetation and washed up zostera, and it seems as if they stop here before going further up into the rivers. Great quantities however come into the coasts at places where no fresh water runs out; they remain then in the salt water, the stock of eels in which is mainly recruited in this manner and not only by the older yellow eels migrating out from fresh water.

The glass-eels taken during their migration out at sea have always had a quite empty digestive tract; they have not yet begun to feed, and corresponding to this the pigmentation is extremely slight. When they have found a resting place, they begin to feed and the pigmentation advances. Their food is chiefly Daphniæ and larvæ of insects.

If a glass-eel in which the pigmentation is as described above is starved, we find that this does not advance. Thus I have kept some glass-eels in summer from the middle of May to the end of August; they got nothing to eat, only the water (salt water) was renewed several times. At the end of this time they had still quite the same appearance as when captured, whilst all the specimens of the

0-group out in the open had assumed all the appearance of the eel. A single specimen lived till one of the last days in October and was then still distinctly a »glass-eel«.

How large are the elvers when they come to our coasts? And what is their growth during the first year they live there?

On these points we have the detailed investigations of A. C. Johansen (in the paper already cited), who comes to the following result: »the glass-eels which appear in our waters and run up the water-courses in spring (March—April), have an average length of 70—72 mm. In June the majority have become pigmented, and the average length is now reduced to 65—68 mm. Later in the summer they again begin to grow in length, but the growth is so slow that their average length in the next spring is only ca. 80 mm.« Johansen also gives tables of measurements which show that the glass-eels actually decrease in size, after they have arrived in our waters. — This peculiar condition has now become more comprehensible, when it is taken in conjunction with the great transformation undergone by the eel in its larval stage, during which a considerable reduction in size occurs. It is thus — as Joh. Schmidt points out in his paper already mentioned — the last stage of this metamorphosis, which is passed here in our fresh water or at our coasts.

Table 5.

	Mouth of Tang River. Great Belt, 7th May 1906. Shrimp net with bobinet.	**Ribe River.** 28th May 1906. Shrimp net with bobinet.	**Audebo. Lamme Fjord.** 12th June 1906. Shrimp net with bobinet.
mm.			
85			
84			
83			
82	1		
81	3		
80	1	1	
79	1	2	
78	7	5	1
77	9	7	2
76	5	7	
75	17	6	3
74	11	6	5
73	9	10	15
72	9	13	15
71	12	13	18
70	5	23	37
69	2	9	23
68	7	6	30
67	3	7	27
66	1	3	16
65	3	2	20
64			4
63			10
62			6
61			
60			

As an illustration of the size of the immigrating glass-eels, Table 5 gives the measurements of glass-eels taken in May and on June 12th 1906. Even so late as this therefore, the immigration does not seem to have been concluded at Audebo in Lammefjord. The fresh water of Lammefjord Lake flows out here into the fjord and forms at times a very strong current, in which we see that eels of the 0, I and II-groups and somewhat larger are working their way up in large quantities. — It will be seen from the Table that the size of the glass-eels varies somewhat at the different places; at Audebo where the catch was made in the middle of June, their length is obviously less than at the other two places; but as the pigmentation was not greater in the specimens from Audebo, we cannot directly compare this with the condition described by Johansen.

After June 12th I have only once (on the 23rd of the same month) taken and measured a large number of glass-eels; it was in a small brook at Frederikshavn. The pigmentation was perhaps somewhat more developed than in typical glass-eels and there were traces of incipient deposition of guanin crystals in the peritoneum in some of them. Their size in cm. is seen in Table 6. None measured 73 mm. or above and a relatively large number was at ca. 65 mm. Thus they were somewhat smaller than those above-mentioned (Table 5).

Table 6.

Brook at Frederikshavn.

Shrimp net with bobinet., 23rd June 1906. 0 = glass-eels. x = dark pigmented eels.

14		
13	x	
12	x	
11	x x	
10	x	
9	x x x	
8	x x x x	
	x x	
7	0000000000000000000000	a number not measured.
	0000000000000	
6	00	
5		

Later in the summer I have taken and measured a few of the 0-group; they always had the ground-colour of the older eels, even on the belly, but could however be distinguished from the next years's group by their small thickness and, from the middle of July on, likewise by the method of measurements; see Table 7 (column 5 fig.), p. 29. Their growth in summer, which had not yet begun on July 11th (Table 7), now proceeds quickly but is again quickly ended, so that on the 10th and 23rd September we find them at size 7—9½ cm. with a very distinctly marked maximum at 8 cm. Next spring, before growth again begins, they have the same size (see Tab. 1—3), and their whole increase in growth in the first year is thus ca. 1 cm.

I. Group.

On the 1st of May (date of arrival) the specimens of this years group have been 1 year in our waters. The majority measure 8 cm. in length (see the previous

Table and Tables 1 and 2); they cannot be distinguished by the measurement-method as a special group from the glass-eels before the month of July; so far, the designations 0 and I group are not quite correct until that time, and it is only by the difference in shape that we can separate these years groups.

Table 7.

Growth of the I Group from May—September 1906. In columns 3 and 4 the II. Group is indicated.

	Audebo.	Ribe River.	Holbæk Fjord.	Struer.	River at Faxe.	Struer.	Struer.	
	$^{15}/_{5}$ 1906.	$^{28}/_{5}$ 1906.	$^{12}/_{6}$ 1906.	$^{18}/_{6}$ 1906.	$^{11}/_{7}$ 1906.	$^{17}/_{8}$ 1906.	$^{20}/_{9}$ 1906.	
cm.								cm.
25			6	1				25
24			5	3		3		24
23			8	2			1	23
22			5	10		6		22
21		1	2	11 III		8	4	21
20		1	13 III	15 III		5	3	20
19		2	5	6	1	3	5	19
18	1		9	7	1	2	10	18
17	1	2	13	11	1	2	10	17
16		6	15	11	3	6	10	16
15	3	4	18	15	1	3	13	15
14	3	7	22	19		6	19	14
13		14	23 II	21 II	2	7	20 I	13
12	1	17	14	11	3	8	19	12
11	4	17	23	17	9	6	15	11
10	10	46	14	15	31 I	10 I	12	10
9	86	84	21 I	22 I	29	8	17	9
8	132 I	119 (25) I	37	27	17	10	19	8
7	36	34 (94) 0	26 (Many of	2 (5) 0	67 0	20 0	7	7
6	glass-eels = 0	(1)	(4) these 0	(3)	14		1	6
5	group not in-	The figures	group					5
4	cluded in the	in brackets	glass-eels).					4
3	Table.	give the num-						3
2		ber of glass						2
1		eels.						1

Table 7 shows the growth of the I group in the course of the summer; as specimens of the 0, II and III groups are included here, I have marked their maxima with Roman figures so that they may easily be distinguished from one another. — By following the figure I from the middle of May to the end of September we readily observe, that the growth is first detected on July 11th and that the maximum of the group moves from 8 to ca. 13 cm. during a whole growth-period, which gives therefore a growth of ca. 5 cm. for the majority of this year's group in the course of the summer, whilst its limits may be placed at ca. $9^1/_2$—17 cm. at the time when the growth ceases. In the next spring we meet it at the same size under the designation of II group; see Table 7

columns 3 and 4, and compare with Table 2, columns 2 and 3. — It will scarcely be clear from the tables alone, that the upper limit of this group in autumn must be put at ca. 17 cm.; the direct evidence of this will be given in describing the next group, and I may refer at the same time to what I have said on p. 24 concerning the »scale-limit«.

A very large number of this group was taken in the course of the summer with the bobinet shrimp net. The fishing grounds were almost always on the margin of rotting Zostera, which is so often found washed up on the beach and lies half on land and half in the low water at the margin. The shrimp net or shove net must then be used as a shovel and the eels are shaken out of the weeds into it. It is surprising the quantities of the eels that can thus be found in a »shovelful« of Zostera. The same method can be used where there is a rich algal vegetation in low water (where one can wade), for example, in the western part of Holbæk Fjord, where great clumps of Chætomorpha linum (Hør) conceal quantities of small eels and also larger, up to ca. 30 cm. in size, in their entangled masses. On quiet warm, sunny days in June—July a quantity of small and a number of larger eels can be taken in this manner. One need only be dexterous in fishing, the more so the larger the eels are. When they are so large as 20 cm., it becomes difficult to catch them in quantities by this method; they are then too rapid in their movements. It is thus difficult to determine the presence of a year's group, the maximum of which falls at 23—24 cm., and this also has the result that the tables seldom show a distinct group-limit at 17 cm.

That these small 1—$1^1/_2$ year old eels are really only found in fresh water or like a fringe along the coasts at suitable places — which would be a parallel to the occurrence of the 0-group of the plaice in the bottom-stages — I will not maintain. It is quite probable, that just these masses of sea-weed offer very favourable conditions with regard to temperature and food — but the conclusion, that these small eels could not live in the summer time, for example, in the Zostera-belt where indeed the large eels occur in such large numbers, would be too hasty. To find them in large numbers in deep water is however a difficult matter; we find single specimens now and then entangled in the blades of Zostera taken in the seines.

Later in the summer or autumn the eels — not only the small — leave the tang-margin or algal vegetation along the coasts and move out into deeper water. The period is somewhat different round about the Danish fjords. At Seden Strand (Odense Fjord), where a quantily of small eels was living in May in a dense and low algal vegetation near the margin, they had already moved out in July; in the beginning of October at any rate they had disappeared. — the eels there belong to the II, and III groups; 0 and I groups were extremely sparsely represented (see Tab. 2, column c). — In Holbæk Fjord, where many eels of the I, II and III groups had lived in June in the algal vegetation in low water, none were to be found anywhere at the end of September; the algal vegetation certainly had broken loose there; along with the washed up Zostera it formed a huge fringe along the beach, but this housed no eels. At Struer on the other hand they were very numerous under the washed-up Zostera even on the 20th of September.

The distribution of the I group is however not so regular that it can be

found everwhere in summer where there is rich algal vegetation at low water or a considerable bed of washed-up Zostera on the beach. As mentioned it was represented this year by very small numbers in Odense Fjord at Seden Strand at the end of May; in June I searched in vain for it in Klosterhavn at Nykjøbing Mors; and at Lindholm near Stege only a few specimens of it were taken in the beginning of the same month.

II. Group.

The specimens of this year's group have been 2 years in our waters on the 1st of May (date of immigration).

The eels have now become quicker in their movements and are more distributed, so that one cannot catch the same quantities of them with the shrimp shove-net as of the previously mentioned annual groups; thus in several of our tables this group is very slightly represented, e. g. Table 7. — Nevertheless there can be no doubt about the lower limit of the approximate average size of its specimens; this appears partly from what has been said above regarding the limits of the I group, and we must therefore place the lower limit of the II group on the date of immigration in spring at ca. $9^1/_2$ cm. and its maximum at ca. 13 cm.

Table 8.

Growth of the II group from May—September 1906.

	Seden Strand. $^{31}/_5$ 06.		At Stege. $^{7}/_6$ 06.		Holbæk Fjord. $^{12}/_6$ 06.		At Struer. $^{18}/_6$ 06.		Holbæk Fjord. $^{29}/_6$ 09.		At Struer. $^{17}/_8$ 06.		At Struer. $^{13}/_9$ 06.		
cm.															cm.
25	2				6		1		3						25
	14		1		5		3		1		3				
23	11		3		8		2						3		23
	21	III	3		5		10		3		6		4		
21	8		5		2		11	III	3		8		3		21
	10		2		13		15		3		5		1		
19	6		3		5		6				3		10	II	19
	8		1		9		7		4		2		4		
17	15		2		13		11		4		2		3		17
	10		1		15		11		6		6	II	4		
15	18		3		18		15		6	II	3		5		15
	30		3		22		19		4		6		6		
13	25	II	11		23	II	21	II	2		7		13	I	13
	37		24		14		11		4		8		19		
11	40		47	II	23		17		11		6		7		11
	17		32		14		15		12	I	10	I	3		
9	11	I	12	I	21	I	22	I	11		8		2		9
	1		3		37		27		14		10		4	0	
7	2	0	5	0	26		7	0	16	0	20				7
					4		3		4						
5															5
3															3
1															1

This is also shown directly in Table 8, which likewise shows the growth of this year-group through the summer. The further we get into the summer the Table becomes less exact owing to the increasing difficulties of capture; we cannot therefore directly accept the maximum which appears in the last column as 19 cm.,

Table 9.

Scale-groups 1 and 2 = Year-groups III and IV.
Danish waters, May June 1906.

cm.	♂ +	♂	♀	cm.
41	2 2			41
39				39
37				37
35	2 2 2

as the real maximum of the group; it now lies considerably higher, as will appear later. — The upper limit of the group is far more difficult to determine; that it agrees with the scale-limit in spring and must therefore be placed between 17 and 18 cm. follows from what has been said earlier on the upper limit of the I group in autumn, and appears further very distinctly from Table 8, cols. 1 and 4 and Tab. 7, cols. 3 and 4; but when growth progresses, the measurement-method is no longer of use, partly on account of the difficulties of obtaining material, partly because this and the following year's group cannot be separated into 2 groups by this method. To find the limit which divides the II and III groups in autumn we must therefore investigate the scales.

It has been mentioned on an earlier occasion, that these are laid down in the skin of the eel when it becomes ca. 18 cm. long, which again indicates that it is just the specimens of the II group which begin in summer to form the central zone of the scale, the growth of which is ended in autumn.

As specimens of a year's group even at this size keep together somewhat in growth, it is a highly probable supposition that at any rate the great mass of them will also form their scales in the same summer. This view confirms, for example, what we found fairly distinct in Tables 7 and 8, (1) that the upper limit of the II group in spring is = the scale-limit, (2) that its great mass passes this limit in the course of the period of growth, so that the maximum of the group is to be found over ca. 20 cm. at the end of this period, and (3) that its lower limit is the scale-limit at this time.

It is thus by a combination of our two methods, that we succeed in being able to determine the limits of the II group in autumn, or what is the same: the limits of the III group in the following spring before growth begins. The measurement-method shows us, that the »mass« of the group passes the scale-limit in the course of summer, so that its maximum is to be sought for above this; but it cannot determine this point exactly; by means of the scale investigations, however, we find both the limits and even the maximum of the group (see Tables 3 and 9). Thus all the specimens indicated by 1 in Table 3 are of the II group, which have indeed scales but have not completed the growth in length, so that the maximum the Table shows would be higher at the end of the period of growth. In Table 9 the group is seen in the following spring; as it is after the date of immigration, it is now called group III; but its limits and maximum are still as in September—October of the previous year when it was known as the II group.

Whilst the average growth of the eel in the first year is 1 cm., and 5 cm. in the second, it is ca. 10 cm. in the third; after this the yearly growth again becomes less.

The growth of the eel in the fourth year and onwards is very clearly shown in the tables.

In using these it has to be remenbered, that the figures 1, 2, 3 etc. indicate the number of annual rings in the scales, i.e. the age of these and not of the eel, which is found by adding 2 after the necessary correction to the point of starting. From the middle of July this is absolutely necessary, as the new zone

is always included, whether it is clearly in process of growth or is completed. On this method of procedure, which is the only one practically possible, it follows

Table 10. Eels from Roskilde Fjord. Small-meshed seine and eel seine. 18.—19. May 1906.

cm.	♂+	♂	♀	cm.
60				60
59				59
57				57
55			4 4	55
53			4 5 5	53
51			4 5 5	51
49			4 4	49
47			3 3 4?4 5	47
45			3 4 4 5	45
43			3? 4 4	43
41			3 3 3 4?	41
39		4	2?2 3 3 3 3 4	39
37		3	3 3 3 3 4	37
35	2	3 3 3 3 3 3 3 3 3 3	2 3 3 3 4	35
33	2 2 2	3?3?3 3 3 3 3 3 3 3 3 3	2 3 3 3 4	33
31	2?2 2 2 2 2	3?3 3 3 3 3 3 3 3 3 3 3 3 3	2 3	31
29	2?2?2 2 2 2	3 3 3 3 3	2 2 2 2	29
27	2 2 2 2 2	3 3	2 2 2	27
25	2 2 2 2 2	3?	2 2 2	25
23	[1]		1	23
21	2?2			21
19	2 2			19
17	1 1 1 2 2			17
15				15

that too great an age is given to the scales (and therefore the eel), as the numbers only become quite correct at the beginning of the next growth-period; thus the specimens of the I, II, III etc. groups in May—June change the sign from the middle of July and must now be sought for in the II, III, IV etc. groups, which must be remembered in comparing groups from different periods of the year.

Table 11.

Nyborg Fjord. Eels taken by eel seine. 21.—30. July 1906.

cm.	♂	♂	♀	cm.
91				91
89	♂	♂	♀	89
87	+			87
85			10	85
			8	
83				83
			12	
81				81
79				79
77			7 8	77
75				75
73			8	73
71			7	71
			7	
69			6	69
67			6 7	67
			5	
65			6 6 7 8	65
			6 7	
63			5 6 6 6 7	63
			6	
61			5 7 7 8 8	61
			5 6 6 7 8	
59				59
			6 6 7	
57			5 5 5	57
			5 5 5 5 5	
55			5 5 6 7	55
		4 4	5 5 5 6	
53		4 4 4	5 5 5 5 6	53
		4 4 4 4 4 4 4 4	5 5	
51		4 4 4 4	5 5 5 5	51
		4 4 4	5 5	
49		4 4	5 5	49
		4 4	5	
47		4 4 4 4 4 4		47
		4 4 4		
45	6	3 4 4 4	5 5 5	45
		3 3 3 3 3 3	4 4 4 4 4 4	
43		3 3 3 3 3	4 5	43
		3 3 3	4 4 4 4 4 4 5	
41		3 3 3 3 3 3	4 4 4 4 4	41
	6	3 3 3	4 4	
39	4 4 5	3 3 3 3 3	4 4	39
	4 4	3 3 3 3 3 3 3 3	4	
37		3 3 3 3 3 3 3 3 3	4	37
		3 3	4	
35	4 4 4 4	3 3 3 3 3 3		35
3	4 4 4	2 2 3 3 3 3 3	4	
33		2		33
2		2 2 3		
31		2		31
	4	2		
29 3		2		29
		2		
27	3			27
		2		
25				25

It appears from the Tables 9 *et seq.*, that we cannot separate the different annual groups of the scaled eels from one another by means of the measurement-method; by means of the scale-investigations, nevertheless, the »groups« are often apparent, so that this designation may be retained though in a somewhat different meaning, as the »scale-group« 1 is identical with the year-group III.

Even in the year-groups III and IV (scale-groups 1 and 2, Table 9) the growth is so even and uniform, that they can each be represented separately by curves, which so far as the first is concerned is only somewhat irregular on account of the difficulties of capture and the like. All the specimens of these groups, both males and females, keep growing together, and the sex is as yet so little marked, that they can only be distinguished in some degree for the last group. With the year-group V (scale-group 3) however, the males and females become separated, the latter beginning to grow more strongly than the former.

Thus arises the well-known difference in size between the males and females, which becomes very marked in the older year-groups. Tables 10 and 11 show the size and year-groups of the yellow eels at Roskilde in May and at Nyborg in July; the males are somewhat less than the females; the largest measures 45 cm., whilst the largest female of the same year-group is 79 cm.

Table 12.

Eels from Kilen at Struer.

cm.	a) Hand-net in Kilen $^{15}/_{9}$ 06. All yellow eels. ♂	b) Traps in outlet to Kilen $^{15}/_{9}$ 06. All silver eels. ♂	♀
69			
67			6
65			5 6
63			
61			
59			
57			
55			
53			
51			
49			
47			
45			
43			
41			
39	4		
37		4	5?5?
		4 44	5
35		3 4 4444	
	3 4	4 44444	5?5 5
33	3?333 4 444	4?444	5 5
	2 3 33 4 444	3 4 4444	5
31	3 3333 4	333 4 44	
	2 3 33 4?4	3 4 4	
29	3 4		
	3 3	4	
27	2		
25			
23			
21			

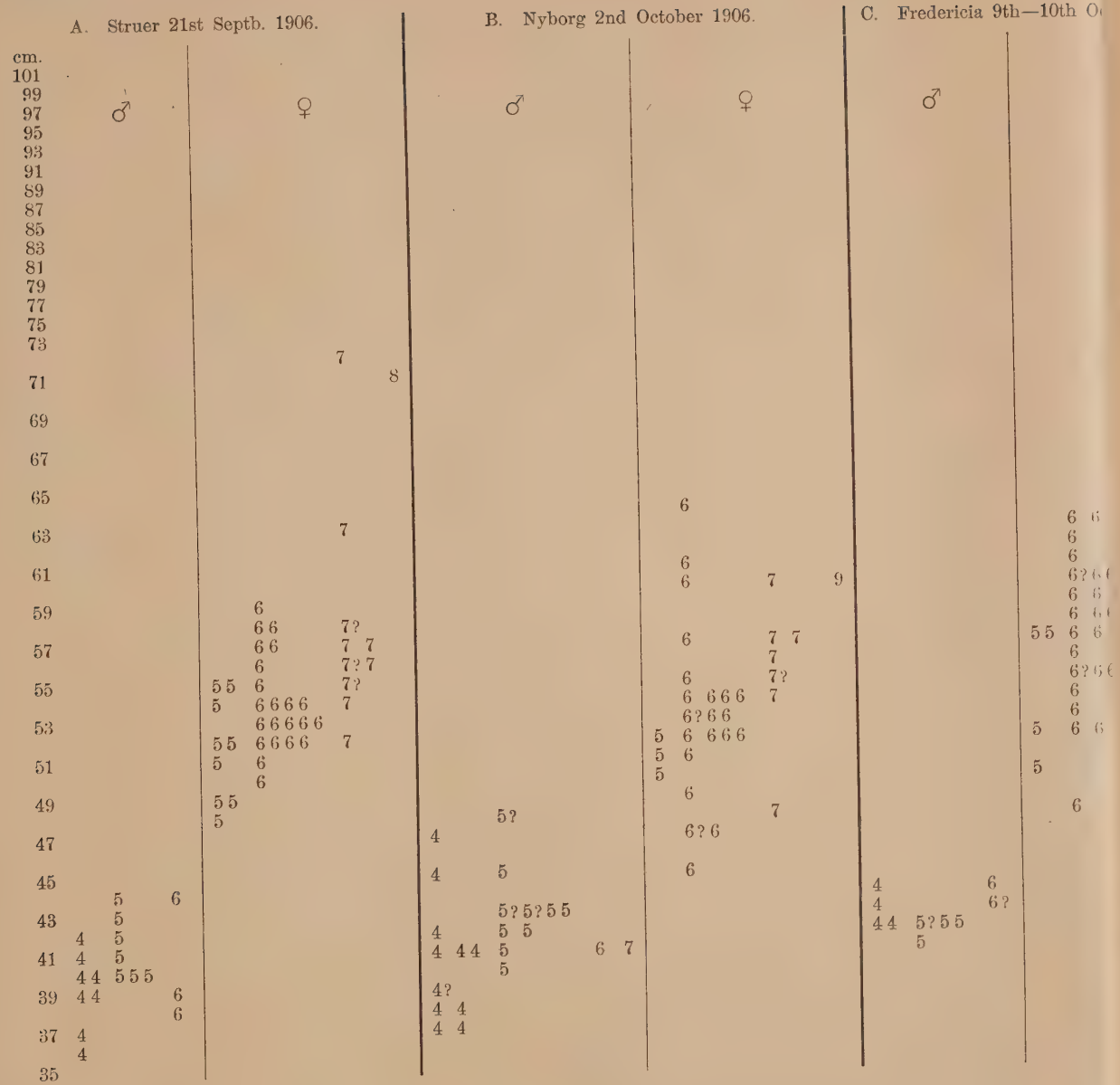
Table 13.

Silver eels from Odense Fjord.

Taken in traps. $^{8}/_{10}$ 06.

cm.	♂	♀
69		
67		
65		
63		
61		
59		6
57		
55		
53		
51		
49		
47		
45		
43		
41	4 5	
39	3	
	4 44	
37	3 4?444	
	4?4	
35	4	
33		
31		
29		
27		
25		
23		
21		

Table 14. Silver eels.



A + B + C.

| | | |

It will be seen from Table 10, that the growth in length for the males is very small, when they have reached the age of 5 years (scale-group 3), and that all the individuals keep together extremely regularly in growth, so that the ordinary curves can be used to represent the separate groups. The growth of the females is shown in Table 11; it is only with the 8th year (scale-group 6) that the annual increase in growth becomes smaller; but it does not cease in specimens which reach a greater age.

The difference in the size of the males and females, which thus becomes more and more evident with the increasing age of the fish, is naturally seen best in the adult or silver eels (see Tables 12—14), where the largest male is 48 cm., whilst the largest female is almost double: 85 cm.; — it will easily be seen also from the numbers on Table 14 that this holds not only for the comparison of the size of single specimens but also for the year-group as a whole. It will likewise be seen that the males become adult or silver 1 year before the females, — and in certain enclosed waters, as »Kilen« at Struer and in part Odense Fjord, where the stock consists almost exclusively of male eels, these become silver somewhat earlier than in the open and larger waters, where both males and females live.

The questions were put forward at the beginning of this paper: how many years lie between the two great migrations of the eel? How old are the silver eels when as adults they leave our waters?

We are able now to answer these; the answer is somewhat different according as we are dealing with males or females. Of the former some few live only $4^1/_2$ years in our waters (e.g. in Kilen and in Odense Fjord), the majority however $5^1/_2$—$7^1/_2$ years, so that about an equal number remain $5^1/_2$ and $6^1/_2$ years here before they migrate as silver eels; much fewer $7^1/_2$ years; once I have found a silver male eel which was $8^1/_2$ years old.

The females become silver later, scarcely before they are $6^1/_2$ years old, the majority not before they are $7^1/_2$ years, and many indeed only become silver when they have been $8^1/_2$ years in our waters. Even older female eels may be found though they must be considered rare. The following brief list gives information on the age of some old silver female eels, their length and growth; they were all taken in traps in the Little Belt during the silver eel fishery there in October 1906.

96 cm.	$12^1/_2$	years	old	5	♀
96 —	$11^1/_2$	—	— ca.	4	-
96 —	$11^1/_2$	—	—	4	-
87 —	$11^1/_2$	—	—	3	-
86 —	$10^1/_2$	—	—	3	-

We come now to the question of the growth in thickness of the eel, which has been occasionally touched upon in the preceding pages. Thus, it was mentioned on p. 18, that it appears from the scale-investigations, that the eel grows very much in thickness in the fourth and fifth years; in these years it grows so very stout that a very broad part is formed along the back, which is covered

Table 15.

Relation between length and weight.
Length in centimeters.
Age given by annual rings on scales.
Age in kvints (100 kvints = 1.1 lbs. Eng.)

Female eels from Nyborg Fjord.
28th—30th July 1906.

cm.	2 annual rings.	3 annual rings.	4 annual rings.	5 annual rings.	6 annual rings.	7 annual rings.
71						
69						108
67						
65						
63						
61				63		87
59						81
						65
57						76
55				49		
						56
53					64	
			36	48 46		
51				41		
			39	49 37		
49				35 37		
			32	36		
47			31 28	27		
			31 21	31		
45			28 27 24			
		23	24 27 18			
43		26 18	30 27 25			
		18 21		22		
41		20 17	23 19 17	21		
		18 14	17			
39		13				
		14 16	14			
37		13 12 12 14	18			
35		10 14 11				
		9				
33	10	8				
	10					
31	8					
	5					
29						
27						
25						
Average of weight:	$15_{,2}$ kvints.		$25_{,3}$ kvints.	$38_{,6}$ kvints.		
» » length:	$38_{,6}$ cm.		45 cm.	$50_{,5}$ cm.		

with scales of corresponding age. It thus appears that the increase in thickness is uneven and occurs especially in certain years; and a consideration of Table 15, which shows the relation between length and weight within certain year-groups, leads to the same result. It will be seen from the Table, that in the fourth year (column 2) the increase in length is 16 %, in weight 66 %; in the fifth year it is 12 % and 52 %; but these numbers must not be considered as absolutely trustworthy and as giving the normal increase; for this purpose the investigations are still of too little extent. But the Table shows the way by which the matter may be unravelled in the future, — a matter which has very great practical inportance and not least with regard to the question of the right size-limit for the capture of eels.

Résumé:

The age and growth of the eel can be determined.

By means of the measurement-method it has been determined, that the eel when it reaches a size of 18 cm. and begins to take on scales, has lived in our waters 2 years, reckoned from the time that it arrives here as montée (glass-eel, elver) on its early migration.

By means of the method of scale-investigation the age of the scaled eels can be determined.

Fig. 1 shows that the scale of the eel consists of a central zone — and the youngest 1-year old scale consists only of this — outside which is found a number of concentric zones or rings, distinctly marked off both from the central zone and from each other. — Sometimes one or more zones are not formed as rings, but only as caps at the ends of the longitudinal axis of the scale.

These zones are annual rings.

That they may be annual rings is based on the periodicity in the life of the eel with changing growth-periods (summer) and resting stages (winter) during which the eels do not grow.

That they probably are annual rings may be concluded from a comparison with the scales of gadoids (and other fishes), where a similar structure points in this direction.

That they really are annual rings is proved by following the growth of the scale through a growth-period; it is laid down, grows and the growth ends, or: a concentric zone is laid down, grows and the growth ends.

The growth of the scale begins in June or as a rule first in July and is ended at the end of September — sometimes (as in silver eels) the growth ends somewhat earlier, seldom later.

The scales are oldest (first laid down) at the lateral line on the centre of the side, and for investigation should be taken from close over the lateral line a little in front of a line from the anus perpendicular to this.

The age of the scales (in years) is found by counting the zones.

The age of the eel is therefore = the age of the scale + 2.

C. G. Joh. Petersen: Om de skalbærende Molluskers Udbredningsforhold i de danske Have indenfor Skagen 1888. 8°. 1162 pg. 2 Kort.

Det videnskabelige Udbytte af Kanonbaaden »Hauch«s Togter i de danske Have indenfor Skagen. 1893. 4°. 464 pg. Atlas i folio.

Indhold: Echinodermata (Petersen), Diatomeer (Cleve), Undersøgelse af nogle Bundprøver (Rørdam), Mollusca (Petersen), Cephalopoda (Posselt), Crustacea malacostraca (Meinert), Hydrografi (Rørdam), Polyzoa (Levinsen), Ascidiæ simplices (Traustedt), Annulata, Hydroidæ, Anthozoa, Porifera (Levinsen), Nogle alm. Resultater (General Results. Engl.) (Petersen).

C. F. Drechsel: Oversigt over vore Saltvandsfiskerier med Kort og Planer. 1890. 4°. 100 pg. Med et Tillæg: »Om Naturforholdene indenfor Skagen« af *C. G. Joh. Petersen*. Med Kort. 4°. 46 pg.

Fiskeri-Beretning for 1888—89, 89—90, 90—91, 91—92, 92—93, 93—94, 94—95, 95—96, 96—97, 97—98, 98—99, 99—1900, 1900—01, 1901—02, 1902—03, 1903—04, 1904—05.

Beretning fra den danske biologiske Station I (1890—91)—XI (1900—1901) findes i de tilsvarende Fiskeri-Beretninger.

I. Fiskenes biologiske Forhold i Holbæk Fjord. 1890—91. 63 pg. Med et Kort.
II. Om vore Kutlingers (*Gobius*) Æg og Ynglemaade. 1892. 9 pg. Med 2 Tavler.
II. On the Eggs and Breeding of our Gobiidæ. 1892. 9 pg. Two Plates.
III. Det pelagiske Liv i Fænø Sund etc. 1893. 38 pg. Tabeller.
III. The Pelagic Life in Fænø Sound etc. 1893. 38 pg. Tables.
IV. Om vore Flynderfiskes Biologi og om vore Flynderfiskeriers Aftagen. 1894. 146 pg. 2 Tavler. 1 Kort og mange Tabeller.
IV. On the Biology of our Flat-fishes and on the decrease of our Flat-fish Fisheries. 1894. 146 pg. 2 Plates. 1 Chart. Many Tables.
V. Den alm. Aal (*Anguilla vulgaris* T.) anlægger før sin Vandring til Havet en særlig Forplantningsdragt. 1896. 35 pg. Med 2 Tavler.
Etc. 64 pg.
V. The common Eel (*Anguilla vulgaris* T.) gets a Particular Breeding-dress before its Emigration to the Sea. 1896. 35 pg. With 2 Plates.
Etc. 64 pg.
VI. Om Rødspætteyngelens aarlige Indvandring i Limfjorden etc. 1887. 49 pg. 1 Kort. 2 Tabeller.
VI. The Yearly Immigration of young Plaice into the Limfjord etc. 1897. 48 pg. 1 Chart. 2 Tables.
VII. Plankton-Studier i Limfjorden. 1897. 23 pg. 1 Kort. 4 Tabeller.

VII. **Separat.** *C. G. Joh. Petersen:* Plankton Studies in the Limfjord. 1897. 23 pg. 1 Map. 4 Tables.

VIII. Om et Skovl-Vaad til Undersøgelse af dybere Farvande. 1898. 24 pg. 10 Figurer.

VIII. **Separat.** *C. G. Joh. Petersen:* An Otter-Seine for the Exploration of Deeper Seas. 1898. 24 pg. With 10 Figures.

IX. Travlinger i Skagerak og det nordlige Kattegat i 1897 og 98. 1899. 56 pg. 1 Kort.

IX. **Separat.** Trawlings in the Skager Rack and the Northern Cattegat in 1897 and 98. 1899. 56 pg. With One Map.

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X. List of The "Aalerusestader" in Denmark, etc. — Smaller Communications. 1899 and 1900. 37 pg.

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XIII. Fiskeæg og Fiskeyngel i de danske Farvande. (Undersøgelser i 1904 og tidligere Aar.) 1903 og 1904. 81 pg.

XIII. Eggs and Young of Fishes in the Danish Waters. (Investigations during 1904 and earlier years.) 1903 and 1904. 85 pg.